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AD-A228 421

R & D STATUS REPORT #6

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DARPA Order No.	:	6325
Contractor	:	Ortel Corporation
Contract No.	:	N00014-88-C-0483
Contract Amount	:	$708,516.00
Effective Date of Contract	:	18 July 1988
Expiration Date of Contract	:	31 December 1990
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Telephone No.	:	(818) 281-3636
Title of Work	:	"Vertical Emitting, Ring Geometry, Ultra-low Threshold and Ultra-high Speed Quantum Well Lasers for Optical Interconnect"
Reporting Period	:	June 1990 - September 1990

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June 1990 - September 1990

The following constitutes the quarterly report for work done on Contract No. N00014-88-C-0483 entitled "Vertical Emitting, Ring Geometry, Ultra-low Threshold and Ultra-high Speed Quantum Well Lasers for Optical Interconnect".

The main emphasis ~~during this quarter~~ was placed on the following efforts: ~~1)~~ Design and implementation of a test station for vertical emitting lasers; ~~2)~~ Ridge waveguide structure and ring configuration lasers; ~~3)~~ Refinement of grating fabrication for repeatability; and ~~4)~~ Single quantum well material investigation.

Keywords: Ring lasers; Optical waveguides; LASERS. (RH)

1. TEST STATION

1.1 Requirements of Test Station

The specific requirement for a vertical emitting distributed Bragg reflector test station are sufficiently different to warrant and in some cases make necessary specialized equipment.

First and foremost, the emission emerges vertically with respect to the wafer plane. In order to facilitate chip level testing, horizontal chip positioning is preferential, resulting in a detector orientation not compatible with conventional edge emitters. The expected vertical beam out of a second order Bragg reflector is dimensionally about two orders of magnitude larger in the longitudinal direction of the laser, the direction which replaces the transverse direction of the edge emitting laser. If single mode operation is obtained, the far field angle is consequently reduced by two orders of magnitude. In order to determine the beam quality, significantly increased resolution in the far field angle is required.

The distance at which the far field approximation can be applied to the direct output beam is increased to the point, that it is more appropriate to use an optical system to generate an image of the far field pattern at a closer distance. The nature of the emitting area of vertical emitting Bragg reflector lasers is more complex than that of an edge emitting laser. Consequently, multiple scans rather than only one lateral and one transverse scan may be required to map the characteristics of the far field pattern.

The near field intensity distribution particular in the longitudinal direction of the laser is a signature of the grating performance. A field of view covering the length of the grating is beneficial for ease of evaluation and stage design.

Visual inspection in order their associate near and far field results with possible material of processing inefficiencies is very desirable. It also aids in alignment.

1.2 Design of Test Station

A mechanical arrangement was conceived with two rotary stages on a bracket such that the respective axis of rotation meet at the locus of observation at 90° with respect to each other.

The first stage with a vertical axis of rotation allows to choose the orientation of the scan or provide the scan in a horizontal plane. The second stage with a horizontal axis of rotation which is rotated by the first stage allows to scan in the vertical plane. The view of the device and the test is via the 5 X or 40 X long working distance objective or near field photodiode or far field imaging lens. The detection is via a far field photodiode or an eyepiece. Future extensions could include a CCD camera. These options are chosen by two mechanical rotation stages as they are used on microscopes to select objectives.

A separate XYZ-stage is utilized to position the laser in the locus of observation. The long working distance objectives are used to view the positioning process in the X- and Y- and focus in the Z-direction. The laser fixture is mounted on a thermo-electric heater/cooler for temperature control. A temperature dependent current source and a thermistor are used to measure the temperature of the laser mount. A needle type probe on its own XYZ-stage is used to establish contact for the drive current of the laser.

The commercial semiconductor laser driver is utilized to control the continues current of the laser and drive the thermo-electric heater/cooler. It is equipped with the GPIB for computer interconnect. A commercial controller card for the rotary stages is inserted into an IBM XT computer for control of the scans. A custom made interface and motor driver integrates all the components to provide coordinated operation as well as test and alignment facilities to the laser test system.

2. RIDGE WAVEGUIDE STRUCTURES

In the last report, the development of ridge waveguides as an alternative lateral optical guiding structure was presented. The continued investigation of these structures revealed that variations in the etch rate are such that use of etch time to control etch depths for ridge wave guide laser structures is not practical for reproducible device fabrication in our laboratory.

The second method utilizing stop etch layers has been refined and the processing recipe has been developed. Photoresist stripe pattern on SiO_2 is under-etched in buffered HF to the desired widths. This allows for experimental variations of this parameters. The full width of 5.5 μm has shown good results. A $H_2SO_4:H_2O_2:H_2O$ etching solution (Sulfuric Acid : Hydrogen Peroxide : Water) of 1:8:40 composition is cooled in a water/ice bath and used for 120 seconds to non-selectively etch into the GaAs/GaAlAs layer structure approximately 1.1 μm deep. A proprietary etching solution is heated in a water bath to 64°C and used for 120 seconds to selectively etch GaAlAs with Al concentrations higher than about 0.2 . This etch removes approximately 4000 Å cladding layer material of Al concentration between 0.4 and 0.6 . It effectively stops at the stop etch layer 1.3 μm below the original top surface. A $NH_4OH:H_2O_2$ etching solution (Ammonium Hydroxide 30% : Hydrogen Peroxide 30%) of 1:24 composition is utilized at laboratory temperature for 15 seconds to remove the overhanging GaAs contact layer with very little etching of the stop etch layer and cladding layers. The resulting ridge exhibits about 5 μm width at the bottom and 3.5 μm at the top when etched such that the laser ridge wave guide exhibits a V-grooved pattern in cross section.

3. GRATING FABRICATION

Continued investigation of grating fabrication in particular on non-planar substrates has been performed. Initial strong non-uniformity require a closer investigation. The etched long one dimensional plateaus used previously where replaced by two dimensional mesas to simulate conditions of ridge waveguide distributed Bragg reflector laser fabrication. Even though these structure are less than 1.5 μm high, they have a strong effect on the spinning of the photoresist/thinner mixture spun on at high speeds. As a result, the photoresist thickness depends on the position with respect to the center of the spinner and therefore, orientation of the laser with respect to the radial direction during the spinning process. Compromise conditions there found to get acceptable grating definition in the photoresist upon holograph exposure. After baking the grating in the photoresist is transferred into the GaAlAs by etching for 20 seconds in a H_2SO_4:H_2O_2:H_2O solution (Sulfuric Acid : Hydrogen Peroxide : Water) of composition 1:8:285 at laboratory temperature. The resulting grating in the GaAlAs is about 500 Å deep. The depth is reproducible as verified by scanning electron microscope (SEM) investigations. For thinner photoresist, the grating can be extended right up to the lower slope of the mesa.

First distributed Bragg reflector ridge waveguide lasers have been fabricated. A 950 μm long active region is directly coupled to a 500 μm long second order retro-reflecting grating. Initial testing indicates lasing, farther testing will follow.

4. SINGLE QUANTUM WELL MATERIAL INVESTIGATION

Experiments on the degradation of single quantum well lasers of the oxide stripe type where continued. The efforts focused on the possibility that strain due to the SiO_2-semiconductor interface was accelerating the aging of the devices. To explore this hypothesis, one set of lasers was fabricated with a 1000 Å thick SiO_2 and another set with a 2500 Å thick SiO_2 layer. Lasers were mounted, characterized and operated at constant current at a heat sink temperature of 80-90°C . Then they were re-characterized at regular intervals. The degradation rate for both groups of devices was similar.

In an attempt to reduce the strain further, lasers were fabricated with an n-type blocking layer on top of the regular cladding layer. These devices do not employ any SiO_2 layer but relay on an additional n-type GaAs layer creating a reverse biased p-n-junction. In the region in which current is to be injected, the n-type blocking layer is etched away. As a control, the n-type blocking layer was completely removed on one piece of the wafer, and standard oxide stripe lasers were fabricated. Eight of the n-type blocking layer and eight of the control devices were subjected to the above introduced constant current 80-90°C heat sink temperature burn in procedure. Both groups showed the same degradation rate. More of these lasers will be burned in to develop better statistics.

5. FUTURE INVESTIGATION

The established procedures are to be utilized to fabricate more single quantum well ridge wave guide distributed Bragg reflector lasers and the developed test stage is to be utilized to measure the device characteristics. New ring lasers with ridge wave guide are to be fabricated and tested and second order gratings are to be integrated into the rings and the resulting lasers are to be tested.